UNITED STATES PATENT APPLICATION FOR GRANT OF LETTERS PATENT

PATRICK HOSEIN
TAO WU
INVENTORS

Common Rate Control Method for Reverse Link Channels in CDMA Networks

5   COMMON RATE CONTROL METHOD FOR REVERSE
LINK CHANNELS IN CDMA NETWORKS

RELATED APPLICATIONS

This application claims priority under 35 U.S.C. § 119(e) from the following U.S.

10   provisional applications: Application Serial No. 60/478,798 filed on June 16, 2003,

Application Serial No. 60/479,013 filed on June 17, 2003, and the application of Tao Wu,

Patrick Hosein, and Anthony C.K. Soong titled "Ericsson Generalized Common Rate

Control Algorithm" filed October 7, 2003 (serial number not assigned). These

applications are incorporated in their entirety by reference herein.

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BACKGROUND OF THE INVENTION

In code division multiple access (CDMA) networks, the mobile stations share a

reverse link channel and may transmit simultaneously on the reverse link channel.

During transmission, each mobile station spreads its transmitted signal with a spreading

20   code selected from a set of mutually orthogonal spreading codes. The base station is

able to separate the signals received from the mobile stations by a correlation process.

For example, if the base station desires to receive the signal transmitted by mobile

station A, the base station correlates the received signal with the spreading code used

by mobile station A to despread the signal from mobile station A. All other signals will

25   appear as noise due to lack of correlation. The base station can despread signals from

all other mobile stations in the same manner.

CDMA networks are interference-limited systems. Since all mobile stations

operate at the same frequency, internal interference generated within the network plays

a critical role in determining system capacity and signal quality. The transmit power from

30   each mobile station contributes to the noise floor and needs to be controlled to limit

interference while maintaining desired performance objectives, e.g., bit error rate (BER),

5   frame error rate (FER), capacity, dropped-call rate, coverage, etc. If the noise floor is

allowed to get too high, widespread outages may occur. An outage is considered to

occur when the power required to maintain minimum signal quality standards is greater

than the maximum transmit power of the mobile station.

Rate control is one technique used to control the transmit power of a mobile

10   station in a CDMA network. In general, the power required to maintain a desired signal

quality increases as the data rate for transmission increases, and decreases as the data

rate for transmission decreases. When a mobile station is commanded to transmit at a

given data rate, the mobile station will transmit at the minimum power level needed to

maintain acceptable signal quality standards. Thus, one way of controlling the transmit

15   power of a mobile station is to dynamically adjust the data transmission rate of the

mobile stations depending on reverse link load.

One rate control technique is known as common rate control. With common rate

control, all mobile stations that need to transmit data in the reverse link are allowed to do

so. Each mobile station initially begins transmitting at a specified minimum rate

20   (sometimes called the autonomous rate) and then, depending on load of the base

stations in its active set, is allowed to vary its transmission rate. The base stations

periodically estimate the reverse link load and compare the estimated reverse link load

to a target load. If the load is below a target threshold, a base station commands the

mobile stations in its cell to increase their transmission rate. Conversely, if the load is

25   above the target threshold, a base station commands the mobile stations in their

respective cells to decrease their transmission rate. In some cases, the base station

may command the mobile stations to hold their current transmission rate.

With common rate control, a base station broadcasts a single up/down/hold rate

control command to all mobile stations in a cell or sector and all of the mobile stations

30   respond to the extent that they are able. That is, when a base station commands the

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5   mobile stations in a cell to increase their transmission rate, all mobile stations in the cell except those already transmitting at maximum power will increase their transmission rate. When a base station commands the mobile stations in a cell to decrease their transmission rate, all mobile stations except those already transmitting at minimum power will decrease their transmission rate. Thus, common rate control results in

10   significant fluctuations in load at the base station. These fluctuations are taken into account when setting the target load. Increasing the target load, in general, will increase system throughput at the risk of more frequent outages. Decreasing the target load will reduce outages at the cost of decreased throughput. The target load is therefore selected to balance system throughput against the probability of outages.

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SUMMARY OF THE INVENTION

     The present invention comprises a method and apparatus for implementing common rate control in a reverse link channel in a CDMA network. A base station periodically (e.g., once per frame) estimates the reverse link load and broadcasts a

20   quantized load indication to mobile stations transmitting on the reverse link channel. The mobile stations dynamically adjust their data transmission rate at least in part on the periodic load indications from the base station. In one embodiment, the mobile stations calculate a load tracking value based on two or more periodic load indications, and then calculate a rate change probability as a function of the load tracking value. The mobile

25   stations selectively change their transmission rate responsive to a current load indication based on the rate change probability. The rate change probability determines the probability that the mobile stations will change its data transmission rate in the current evaluation period. Consequently, some number of mobile stations will change rates, and some other number of mobile stations will continue to transmit at their current rate.

5   In some exemplary embodiments, a mapping function is used to map load

tracking values to corresponding rate change probabilities. The probability generally

varies with distance of the load tracking value from a desired target value. In some

embodiments, the rate change probability varies linearly with distance from the target

value over a defined range of load tracking values. The defined range in which the rate

10   change probability varies linearly may be the entire load tracking range, or a portion of

the load tracking range. In other embodiments, the mapping function may use a non-

linear function to map load tracking values to rate change probabilities. In other

embodiments, the load tracking function itself may evaluate to a probability so a

separate mapping function is not required.

15   In some embodiments of the invention, the rate change probabilities may be

mobile station dependent, user class dependent, or quality of service (QoS) dependent.

For example, a sliding window may be employed to make rate change probabilities

dependent on the current data transmission rate or current transmit power level of the

mobile station. As a further example, users may be divided into two or more distinct

20   classes, which are assigned biasing factors to bias the rate change probabilities in favor

of a particular group or class.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram of an exemplary wireless communication network according

25   to one or more embodiments of the present invention.

Fig. 2 is a diagram of exemplary functional details for a radio base station

according to the present invention.

Fig. 3 is a functional block diagram of an exemplary mobile station according to

the present invention.

5   Fig. 4 illustrates an exemplary load curve for a base station using common rate

control according to the present invention.

Fig. 5 illustrates an exemplary load tracking curve for a mobile station using

common rate control according to the present invention.

Fig. 6 illustrates an exemplary load curve for a base station using common rate

10   control according to a second embodiment of the present invention.

Fig. 7 illustrates a rate dependent sliding window for common rate control

according to the present invention.

Fig. 8 illustrates a power dependent sliding window for common rate control

according to the present invention.

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DETAILED DESCRIPTION OF THE INVENTION

Turning to the drawings, Fig. 1 illustrates an exemplary wireless communication

network 10 in which the present invention may be implemented. Network 10 may be any

packet-switched communication network, for example, cdma2000 wireless network

20   according to the IS-2000/2001 families of standards. However, those skilled in the art

will appreciate that the wireless communication network may be configured according to

other standards, such as Wideband CDMA (WCDMA) standards, for example.

Network 10 includes a Packet-Switched Core Network (PSCN) 20 and a Radio

Access Network (RAN) 30. The PSCN 20 provides connection to one or more Public

25   Data Networks (PDNs) 50, such as the Internet. The PSCN 20 includes a packet data

serving node (PDSN) 22, a gateway 24, and an IP network 26. The details of the PSCN

20 are not material to the present invention and, therefore, the PSCN 20 is not

discussed further herein. The RAN 30 provides the radio interface between the mobile

stations 100 and the PCSN 12. An exemplary RAN 30 comprises a Packet Control

30   Function (PCF) 32, one or more Base Station Controllers (BSC) 34, and a plurality of

5   Radio Base Stations (RBSs) 36. BSCs 34 connect to the RBSs 36 to the PCF 32.

Mobile stations 100 communicate with the RBSs 36 via the air interface as defined by

the appropriate network standards, such as the IS-2000 family of standards.

Fig. 2 illustrates a functional diagram of an exemplary RBS 36 according to one

embodiment of the present invention. It will be appreciated that the present invention is

10   not limited to the RBS architecture illustrated in Fig. 2, and that other RBS architectures

are applicable to the present invention. The functional elements of Fig. 2 may be

implemented in software, hardware, or some combination of both. For example, one or

more of the functional elements in RBS 36 may be implemented as stored program

instructions executed by one or more microprocessors or other logic circuits included in

15   RBS 36.

As shown in Fig. 2, RBS 36 includes transmitter circuits 38, forward link signal

processing circuits 40, receiver circuits 42, reverse link signals processing circuits 44,

and control and interface circuits 46. The transmitter circuits 38 include the necessary

RF circuits, such as modulators and power amplifiers, to transmit signals to mobile

20   stations 100. The forward link signal processing circuits 40 process the signals being

transmitted to the mobile stations 100. Forward link signal processing may include

digital modulation, encoding, interleaving, encryption, and formatting. The receiver

circuits 42 comprise the RF components, such as a receiver front end, necessary to

receive signals from the mobile stations 100. Reverse link processing circuits 44

25   process the signals received from the mobile stations 100. Reverse link processing may

include, for example, digital demodulation, decoding, de-interleaving, and decryption.

Control and interface circuits 46 coordinate the operation of the RBS 36 and the mobile

stations 100 according to the applicable communication standards and interface the

RBS 36 with the BSC 34. The forward link processing circuits 40, reverse link

30   processing circuits 44, and control and interface circuits 46 may be integrated in a single

5   processor, or may be implemented in multiple processors, hardware circuits, or a

combination of processors and hardware circuits.

Fig. 3 is a functional block diagram of an exemplary mobile station 100 according

to one embodiment of the present invention. As used herein, the term "mobile station"

may include a cellular radiotelephone, a Personal Communications System (PCS)

10 terminal that may combine a cellular radiotelephone with data processing, facsimile, and

data communications capabilities; a Personal Data Assistant (PDA) that may include a

pager, Web browser, radiotelephone, Internet/intranet access, organizer, calendar, and

a conventional laptop and/or palmtop receiver or other appliances that include a

radiotelephone transceiver.

15 Mobile station 100 includes a transceiver 110 connected to an antenna 120 via a

multiplexer 130 as known in the art. Mobile station 100 further includes a system

controller 140, and a user interface 150. Transceiver 110 includes a transmitter 112 and

a receiver 114.   Transceiver 110 may, for example, operate according to the cdma2000,

WCDMA or UMTS standards. The present invention, however, is not limited to use with

20 these standards and those skilled in the art will recognize the present invention may be

extended or modified for other standards.

System controller 140 provides overall operational control for the mobile station

100 according to programs instructions stored in memory. System controller 140 may

comprise a microprocessor or microcontroller and may be part of an application specific

25 integrated circuit (ASIC). Memory represents the entire hierarchy of memory in a mobile

station 100. Memory provides storage for data, operating system programs and

application programs. Memory may be integrated with the system controller, or may be

implemented in one or more discrete memory devices.

User interface 150, typically comprising a keypad 152, display 154, microphone

30 156 and/or speaker 158. Keypad 152 allows the operator to enter commands and select

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5   menu options while display 154 allows the operator to see menu options, entered

commands, and other service information. Microphone 156 converts the operator's

speech into electrical audio signals and speaker 158 converts audio signals into audible

signals that can be heard by the operator. It will be understood by those skilled in the art

that mobile station 100 may comprise a subset of the illustrated user interface elements

10   or mobile station 100 may comprise additional user interface elements not shown or

described herein.

The RBS 36 communicates with a plurality of mobile stations 100. In the

exemplary embodiment, the mobile stations 100 transmit data to the RBS 36 over a

reverse link channel that is rate controlled. The reverse link channel is preferably, but

15   not necessarily, one designed for packet data. Multiple mobile stations 100 can transmit

simultaneously on the reverse link channel and the RBS 36 distinguishes their

respective signals by the spreading codes that are assigned to the mobile stations 100

at connection setup. When the RBS 36 despreads the signal received from a given

mobile station 100, the transmission from all other mobile stations 100 appear as noise.

20   The quality of a signal received from a given mobile station 100 by the RBS 36 depends

on thermal noise and the noise generated by all the other mobile stations 100. The total

noise is dependent on the number of mobile stations 100 simultaneously transmitting on

the reverse link and the transmission power of those mobile stations 100.

Signal to noise ratio (SNR) is one measure of the quality of the received signal.

25   To maintain minimum signal quality standards, the mobile station 100 must transmit with

enough power to maintain the SNR of the received signal above a predetermined level.

If the noise floor (thermal noise + noise from other mobile stations 100) gets too high, the

required transmit power to maintain the minimum signal quality standards, may exceed

the maximum transmit power of the mobile station 100. This condition is referred to as

30   an outage.

5   Common rate control is one technique to control the amount of interference on a

reverse link channel. The general aim of common rate control is to maintain the reverse

link load as close as possible to a desired target load so that the number of outages is

maintained at an acceptable level, e.g. 1% while utilizing the reverse link channel to the

fullest extent possible. In most common rate control schemes, mobile stations 100 that

10   have data to transmit are allowed to transmit. Initially, a mobile station 100 begins

transmitting at a very low rate called the autonomous rate, which may for example be a

rate of 9.6 kbps. After a mobile station 100 begins transmitting data, it is allowed to vary

its transmission rate depending on reverse link load. The RBS 36 periodically estimates

the reverse link load and transmits a load indication to all of the mobile stations 100

15   transmitting on the reverse link channel. Each mobile station 100 decides whether to

increase or decrease its transmission rate based at least in part on the load indication

from the RBS 36. Rate adjustment decisions by the mobile stations 100 will tend to

follow the load indications from the RBS 36. If the reverse link load at the RBS 36

increases above the target load, the mobile stations 100 in general will decrease their

20   transmission rate to reduce the reverse link load. Conversely, if the reverse link load at

the RBS 36 decreases below the target load, the mobile stations 100 in general will

increase their transmission rate to increase the load and more efficiently use the reverse

link channel. The rate adjustment decision of an individual mobile station 100, however,

may not follow the load indication at a given time instant, since other factors (e.g., user

25   class, QoS information, power limitations, etc.) may be evaluated in making rate control

decision.

Common rate control requires no rate feedback information from the mobile

stations 100 to the RBS 36, and the RBS 36 broadcasts load indications to all mobile

stations 100 on a common control channel. Consequently, common rate control

30   requires a low signaling overhead and is low in implementation complexity. However,

5   common rate control requires that the target load be adjusted to provide sufficient

margin to account for expected fluctuations in system load. It is therefore desirable that

fluctuations in load be minimized as much as possible so that the target load can be as

close as possible to the maximum load.

Fig. 4 is a graph illustrating reverse link load in a CDMA network implementing

10   common rate control. In Fig. 4, the vertical axis represents the reverse link load, and the

horizontal axis represents time. L_{MAX} is the maximum load beyond which the system is

unstable and outages are likely to occur. L_{MIN} is the load below which the system is

considered lightly loaded.

During operation the RBS 36 periodically estimates the reverse link load and

15   determines the load indication to broadcast to the mobile stations 100 transmitting on the

reverse link. The evaluation period may be once per frame. Evaluation periods longer

or shorter than once per frame are also within the scope of the invention. If

$L(n)$ denotes the estimate of the reverse link load at the nth evaluation period and $b(n)$,

the RBS 36 may determine the corresponding load indication as follows:

$$\begin{aligned}
&if &&(L(n) >= L_{MAX}) &&\{set\, b(n) = 1\}\\
&else\, if &&(L(n) <= L_{MIN}) &&\{set\, b(n) = -1\} &&\text{Eq. 1}\\
&else &&&&\{set\, b(n) = 0\}
\end{aligned}$$

The load indication $b(n)$ may comprise, for example, a one or more reverse activity bits

(RABs) that are transmitted to the mobile stations 100 during each evaluation period.

The mobile stations 100 receive the load indications $b(n)$ from the RBS 36 and

decide whether to change their data transmission rate in the next evaluation period, e.g.

25   frame. Upon receipt of the load indication $b(n)$ from the RBS 36, the mobile stations

100 evaluate a load tracking function to generate a load tracking value. The load

tracking value serves as a mobile station estimate of the reverse link load. The load

5   tracking function is preferably one that filters or smoothes the load indications $b(n)$

received from the RBS 36 over a plurality of evaluation periods and converts the

quantized load indications $b(n)$ into a continuous load tracking value. In this context,

the phrase "continuous load tracking value" means that the value of the load tracking

function may assume any value within a defined range of values. Thus, the load

10   estimation process at the base station converts continuous load estimates into quantized

values and the load estimation process at the mobile station converts the quantized load

estimates back into a continuous load tracking value.

        The load tracking function may be any function that provides a smoothed

estimate of reverse link load from the periodic load indications $b(n)$. If $y(n)$ is the load

15   tracking value, then the load tracking value $y(n)$ may be computed according to:

$$y(n) = \alpha b(n) + (1-\alpha)y(n-1),$$
                              Eq. 2

where the term $y(n-1)$ represents the load tracking value computed at time *n*-1 and the

constant α is a smoothing factor. Eq. 2, in effect, computes a weighted average of the

load indications from the RBS 36 over a plurality of evaluation periods. The value of α,

20   which is in the range of 0 to 1, determines the weight given to the load indication for the

current evaluation period. When set to a value between 0 and 1, the smoothing factor

α causes the weight of a periodic load indication for a current evaluation period to

exponentially diminish in subsequent evaluation periods. When the smoothing factor α =

1, the term $(1-\alpha)y(n-1)$ is 0 so that the load tracking value $y(n)$ will always equal the

25   load indication $b(n)$ for the current evaluation period. When the smoothing factor α

equals 0, the load tracking value $y(n)$ does not change from one evaluation period to

the next.

5   After updating the load tracking value $y(n)$, the mobile stations 100 determine

whether to change rate in the next evaluation period or frame. This rate change

determination is made by mapping the load tracking value $y(n)$ to a rate change

probability $P(n)$. The mobile stations 100 then probabilistically change their data

transmission rate in the reverse link channel based on the rate change probability $P(n)$.

10   One way to implement the probabilistic rate change is to make the rate change

determination dependent on a random event. For example, the mobile stations 100 may

each generate a random number between 0 and 1, and compare the random number

with the rate change probability $P(n)$. If all the mobile stations 100 receive the load

indications $b(n)$ without error, then all the mobile stations 100 should compute the same

15   or nearly the same rate change probability $P(n)$. The only exception would be where a

mobile station 100 has been transmitting for only a few frames. If the rate change

probability is, for instance 0.67, mobile stations 100 generating a random number

between 0 and 0.67 would change data transmission rates. Those mobile stations 100

generating random numbers between 0.67 and 1 would continue transmitting at their

20   current data transmission rates. Thus, some number of mobile stations 100 will change

data transmission rates, and some other number of mobile stations 100 will not, reducing

fluctuations in the reverse link load.

        In one embodiment of the invention, the probability $P(n)$ of changing rate is

dependent upon the distance of the load tracking value $y(n)$ from a target load tracking

25   value as illustrated in Fig. 5. Since the load tracking value of Eq. 2 varies between –1

and 1, the target load tracking value may be set equal to 0 and the mapping of the load

tracking value to a rate change probability may be according to:

$$P(n) = |y(n)| \hspace{4cm} \text{Eq. 3}$$

5   The probability that a mobile station 100 will change rate will depend on how far the load

tracking value $y(n)$ is above or below 0.

There may be some conditions under which the mobile station 100 does not

change rate. For example, if a mobile station 100 transmitting at the minimum rate, it

cannot reduce its rate. Similarly, a mobile station transmitting at the highest rate cannot

10   increase rate. Also, in the mobile station 100 must have sufficient power headroom to

increase its rate even if it is not currently at the maximum rate. If hybrid automatic

repeat request (HARQ) is used, the mobile station 100 may be required to retransmit a

frame at a specified rate, which may be the same rate as the original transmission or at

a higher rate.

15   Fig. 6 is a graph illustrating the reverse link load in an alternate embodiment of

the present invention. In Fig. 6. L_{MAX} is the maximum load beyond which the system is

unstable and outages are likely to occur. L_{MIN} is the load below which the system is

considered lightly loaded. L_T is a target load at which the RBS 36 should operate. The

values L_{MAX}, L_T, and L_{MIN} divide the range of possible load values into four regions,

20   which can be indicated by two bits. In this embodiment, the RBS 36 determines the load

indication $b(n)$ as follows:

$$
\begin{aligned}
&if &&(L(n) > L_{MAX}) &&\{set\, b(n) = 2\} \\
&else\, if &&(L_T >= L(n) > L_T) &&\{set\, b(n) = 1\} \\
&else\, if &&(L_T >= L(n) > L_{MIN}) &&\{set\, b(n) = -1\} \\
&else &&&&\{set\, b(n) = -2\}
\end{aligned}
\qquad \text{Eq. 4}
$$

The load indication $b(n)$ may comprise, for example, a pair of reverse activity bits

(RABs) with the values shown in Fig. 6.

25   In the alternate embodiment shown in Fig. 6, the mobile stations 100 may

calculate the load tracking value $y(n)$ using the load tracking function represented by

5   Eq. 2.   In that case, the load tracking value $y(n)$ will vary in the range of –2 to 2. After

computing the load tracking value $y(n)$, the mobile stations 100 next determine a rate

change probability $P(n)$ based on the load tracking value $y(n)$. Again, the mapping of

the load tracking value $y(n)$ may be dependent on the distance of the load tracking

value $y(n)$ from a reference value. Since the load tracking range is symmetric about 0,

10   the load tracking value may be according to:

$$P(n) = \min\{1, |y(n)|\}$$ Eq. 5

When the load tracking value $y(n)$ is greater than 0, the rate change probability $P(n)$ is

the greater of $y(n)$ and 1. When $y(n)$ is less than to 0, the rate change probability $P(n)$

is the greater of 1 and $-y(n)$. In this example, when $y(n)$ is greater than or equal to 1

15   or less than or equal to -1, the rate change probability $P(n) = 1$. When $Y(n)$ is less than

1 and greater than -1, the rate change probability $P(n)$ varies linearly with the distance

of the load tracking value from 0. This is a bounded linear mapping of $y(n)$ to $P(n)$. By

scaling $y(n)$ so that it assumes a maximum value of 1 and a minimum value of -1, an

unbounded linear mapping from $y(n)$ to $P(n)$ may be obtained. In the exemplary

20   embodiment of Fig. 6, the rate change probability may the mapped linearly to a rate

change probability by the scaling function:

$$P(n) = \frac{|y(n)|}{2}$$ Eq. 6

The scaling function shown in Eq. 6, in effect, maps $y(n)$ to $P(n)$ linearly with respect to

distance over the entire range of possible load tracking values.

25   Those skilled in the art will appreciate that mapping from $y(n)$ to a rate change

probability $P(n)$ can be a general mapping and need not be restricted to the linear

5   mappings. Eqs. 7 and 8 below are mapping functions that illustrate one approach to

calculating rate change probabilities based on an expected load value. In this example, it

is assumed that the load tracking value $y(n)$ varies between −1 and 1. When $y(n) > 0$,

the load tracking value $y(n)$ can be mapped non-linearly to a downward rate change

probability $P_d(n)$ according to:

10
$$P_d(n) = \frac{2y(n)(\beta - 1)}{1 + y(n)(\beta - 1)}$$
Eq. 7

When $y(n) < 0$, the load tracking value can be mapped non-linearly to an upward rate

change probability $P_u(n)$ according to:

$$P_u(n) = \frac{-y(n)(\beta - 1)}{1 + y(n)(\beta - 1)}$$
Eq. 8

In Eqs 7 and 8, β is a load ratio that specifies the ratio of a desired target load to the

15   maximum load. Eqs. 7 and 8 map the load tracking value $y(n)$ non-linearly to a

corresponding rate change probability $P(n)$ such that the expected load following the

rate change will be at a desired target load.

In some embodiments of the invention, the mapping of the load tracking value to

a rate change probability can be made mobile dependent, QoS dependent, or user class

20   dependent. As an example of user class dependent rate change probabilities, assume

that the mobile stations 100 are classified into three classes: gold, silver and bronze. If

γ_i represents a class dependent adjustment factor, a mobile station 100 in class i

computes the rate change probability as follows:

$$
\begin{array}{lll}
if & y(n) > \gamma_i & \{set\ P(n) = \min(1, (y(n) - \gamma_i)/(1 - \gamma_i)\} \\
if & y(n) < \gamma_i & \{set\ P(n) = \min(1, (\gamma_i - y(n))/(\gamma_i + 1)\} \\
else\ if & & \{set\ P(n) = 0\}
\end{array}
$$
Eq. 9

5 Note that values of γ_i are selected such that $\sum_i \gamma_i = 0$ for all classes. If $\gamma_i = 0.5$ for

gold users, $\gamma_i = 0$ for silver users, and $\gamma_i = -0.5$ for bronze users, users in the higher

classes will be favored and will get a larger fraction of the available load.

The calculation of the rate change probabilities of the mobile station 100 may, in

some embodiments, be made mobile dependent. Referring to Fig. 8, a sliding window or

10 mask over the load tracking range is defined for each mobile station 100. The size S_k of

the sliding window may be the same for all mobile stations 100, or may be different for

different classes of users. The size S_k of the sliding window may be fixed for each user

or may be dynamically adjusted. The size of the sliding window will be some value less

than $Y_{MAX} - Y_{MIN}$. As shown in Figure 7, the position of the sliding window for a given

15 mobile station 100 is dependent on the current transmission rate of the mobile station

100. For very low rate users, the sliding window will be near the top of the load tracking

range. For high rate users, the sliding window will be near the bottom of the load

tracking range. For mobile stations 100 operating at transmission rates somewhere in

the middle, the sliding window will be somewhere in the middle of the load tracking

20 range. If R_{MAX} is the maximum transmission rate, is R_{MIN} the minimum transmission

rate, and R_K is the current transmission rate, the position of the sliding window may be

computed according to:

$$T_{MAX} = S_k (R_{MAX} - R_K)/(R_{MAX} - R_{MIN})*Y$$
$$T_{MIN} = S_k (R_{MIN} - R_K)/(R_{MAX} - R_{MIN})*Y$$

Eq. 10

where $|Y_{MAX}| = |Y_{MIN}| = Y$. T_{MAX} specifies the top of the sliding window, while T_{MIN}

25 specifies the bottom of the sliding window.

After computing the load tracking value $y(n)$ for the current evaluation period,

the mobile station 100 compares the current load tracking value $y(n)$ to the sliding

5   window. If the current load tracking value $y(n)$ is within the sliding window, the mobile

station 100 sets the rate change probability $P(n)$ to 0. If the load tracking value $y(n)$ is

outside of the sliding window, the mobile station 100 computes the rate change

probability $P(n)$ as previously described. Those skilled in the art will appreciate that,

instead of setting the rate change probability to 0 when the load tracking value $y(n)$ is

10   within the sliding window, either the load tracking value $y(n)$ or the rate change

probability $P(n)$ could be multiplied by an adjustment factor to reduce the probability of

a rate change.

Applying a rate dependent sliding window or mask as described above will tend

to cause the mobile stations 100 to converge to the same transmission rate. High rate

15   mobile stations 100 will ignore commands to increase transmission rates while

responding to commands to decrease transmission rates. Conversely, low rate mobile

stations 100 will respond to commands to increase transmission rate, while ignoring

commands to decrease transmission rate. As a consequence, the transmission rates for

all mobile stations 100 will tend to converge to a common value.

20   Having all mobile stations 100 transmit at the same rate will tend to reduce

system throughput because mobile stations 100 operating under favorable conditions

will have their data transmission rate constrained by other mobile stations 100 operating

under less favorable conditions. To improve throughput, mobile stations 100 operating

under advantageous conditions should be allowed to transmit at higher rates than mobile

25   stations 100 under less favorable conditions.

Fig. 8 illustrates a method of determining rate change probabilities that are power

dependent. Again, the concept of a sliding window or mask is used. The position of the

sliding window is determined based on the mobile station's current transmit power P_K

5   instead of the mobile station's current rate level R_K. If a given mobile station 100 is

transmitting with low power, the sliding window will be near the top of the load tracking

range. Conversely, if the mobile station 100 is currently transmitting with high power, the

sliding window will be near the bottom of the low tracking range. For a mobile station

100 transmitting at a power level somewhere in the middle, the sliding window will be

10   somewhere in the middle of the low tracking range. The position of the sliding window

may be calculated according to:

$$T_{MAX} = S_k (P_{MAX} - P_K)/(P_{MAX} - P_{MIN}) * Y$$
$$T_{MIN} = S_k (P_{PMIN} - P_K)/(P_{MAX} - P_{MIN}) * Y$$

Eq. 11

where If P_{MAX} is the maximum transmit power, P_{MIN} is the minimum transmit power, and

P_K is the current transmission power of the mobile station 100.

15   When the mobile stations 100 receive the load indication $b(n)$ from the RBS 36,

the mobile stations 100 compute the load tracking value $y(n)$ and compare the load

tracking value $y(n)$ to the sliding window. If the load tracking value $y(n)$ is within the

sliding window, the mobile stations 100 may set the rate change probability $P(n)$ to 0. If

the load tracking value $y(n)$ is outside of the sliding window, the mobile stations 100

20   may compute the rate change probability $P(n)$ as previously described. Mobile stations

100 operating at a low transmit power will tend to ignore commands to reduce

transmission rate, while mobile stations 100 with high transmit power will tend to ignore

commands to increase transmission rate. Consequently, the transmit power for all

mobile stations 100 will tend to converge to a common transmit power level.

25   When all mobile stations transmit at the same power level, the transmission rates

will be dependent on the conditions of the reverse link channel. Those mobile stations

100 operating under better conditions will transmit at a higher rate than mobile stations

5   100 operating under adverse conditions. This rate control method results in

"proportionally fair" rates to the mobile stations 100.

In the case of a mobile station 100 in soft handoff, the mobile station 100 may

combine the load indications $b(n)$ from the RBSs 36 in its active set. Soft combining of

the load indications $b(n)$ to compute the load tracking value may be performed

10   according to:

$$y(n) = \beta\, primary(y_i(n)) + (1 - \beta)\, mean(y_i(n)) \qquad \text{Eq. 12}$$

where $y_i(n)$ is the load tracking value generated on the ith soft link at frame (n). In Eq.

12, the mobile station computes a weighted average of the load tracking value from the

primary RBS 36 and the mean load tracking value from all RBSs 36 in its active set.

15   Alternatively, the mobile station 100 could set the load tracking value equal to the

greater of the load tracking value from the primary RBS 36 and the mean load tracking

value from all RBSs 36.